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CONTENTS

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H. P. Davis, W. W. Swett, and Walter R. Harvey[1]

Introduction

Body weight is the one measurement most extensively used to evaluate growth, condition, and value for beef, and as a basis for calculating feed requirements for cattle. Weight can be determined readily by scales but unfortunately scales of a capacity adequate for weighing cattle are not always available. Thus there is a real need for a basis of estimating weight from some body measurement that can be obtained easily and at a minimum of cost and time.

Many investigations have been made in an effort to provide such a basis by determining relationships between various body dimensions and body weight. In most of these studies, circumference of chest (heart girth) has been found to be the measurement most closely correlated with weight. The Dairy Cattle Research Branch[2] of the U.S.D.A., reported a table of heart girth-weight equivalents from which a measuring tape was prepared. This tape has been used extensively for more than 20 years in connection with D.H.I.A. work and for the estimation of body weight in dairy cattle generally.

It is the aim of this study to utilize additional data now available to increase further the accuracy and reliability of estimating weight from body measurements.

Review of Literature

Early reports of attempts to estimate body weight from body measurements of animals were reviewed by Horn (23) in 1893. He showed that studies in this field had been made as early as in the 18th century and listed at least a dozen workers who reported on the subject over a period of nearly a century, from Thaer in 1809 to Kjellström in 1892. Horn indicated that the measurements most commonly used in these early studies were heart girth and body length. The most reliable method developed during that period, however, appears to have been based on a formula in-

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[2] Formerly Bureau of Dairy Industry.

corporating measurements of paunch circumference, body length and a correction factor.

At least as early as 100 years ago it was the practice of New England cattlemen to use a "girthing chain" in estimating the live weight of cattle, both in evaluating growth and in connection with buying and selling. These chains were constructed of small metal links into which rings were inserted, usually at spaces of six inches. With the chain circumscribing the chest (heart girth) the ring-markers made it possible to estimate body weight with sufficient accuracy to establish a basis for a dealing that was acceptable to both parties in a transaction.

Neither the origin of the girthing chain nor the basis on which it was established is definitely known. It was stated by Horn (23), however, that both tapes and chains were used in Germany to evaluate the weight of cattle during the 19th century.

Efforts Lagged

Efforts to establish more precise methods of estimating body weight from measurements seem to have lagged during the quarter century following the publication of Horn's review, and comparatively few reports appeared. During that period West (45) published a report in 1904 dealing with the estimation of weight in meat cattle from tape line measurements; Matievic (28), also in 1904, developed measurement-weight equivalents for various cattle breeds in Austria and prepared a tape line adaptable for practical use and Woll (46) in 1914 published tables of heart girth-weight relationships for different classes of cattle in varying degrees of condition.

More recently, a notable increase in interest and in research activity has occurred as evidenced by the addition of some 40 reports dealing with the estimation of live weight in cattle and in the buffalo. Since 1900 reports on the subject have been published in at least 14 countries—Africa, Australia, Austria, Brazil, Denmark, England, France, Germany, India, Italy, Jamaica, Norway, Russia, and Sweden—in addition to the United States. The interest since 1950 has been particularly noteworthy.

Weight Estimate Studies

Studies of weight estimation have been reported for approximately 40 different breeds of cattle and for a number of cross-breeds. At least two studies of the buffalo have been made. Dairy, beef, and dual or general purpose cattle have been included. One study was based on animals exhibited at fat stock shows (7). Separate studies have been made of cows, heifers, bulls, steers, and oxen. Studies have included animals varying from early calfhood to late maturity. The number of animals

represented in individual studies has varied from 100 or less to more than 2,350 (24). Paired values in an individual study have exceeded 10,000 (16).

A number of different approaches have been made to the problem of estimating body weight from body measurements. Many investigators, (1, 2, 4, 5, 7, 8, 11, 12, 13, 14, 16, 18, 24, 26, 29, 31, 33, 35, 39, 44, 46) have presented results in the form of tables or graphs to show measurement-weight equivalents. Others (3, 6, 7, 9, 10, 15, 17, 19, 20, 21, 25, 30, 32, 37, 41, 42, 44) have expressed results in terms of correlations or regressions. Some (4, 6, 15, 16, 23, 24, 27, 28, 29, 31, 32, 35, 36, 44, 45) have developed or used a great variety of formulas involving weight measurements and constants adaptable for various breeds and types of cattle of different ages and sizes, and in varying degrees of fatness. A few (22, 23, 34, 38, 43, 44) have concentrated their efforts on testing or comparing techniques, formulas and results reported by others. In addition to the review by Horn (23) of investigations (chiefly European) reported prior to 1893, three reviews of broad coverage (15, 25, 40) have appeared within the past five years.

Studies Are Varied

Reported studies have differed materially with respect to the body measurements used. Some investigators have confined their studies to a measurement-weight relationship based on a single body measurement. Others have compared the measurement-weight relationships for individual measurements varying in number from 2 to 14. In some studies formulas have been developed from a single measurement; in others from several, most of which were in more or less common usage.

A number of unique measurements have been employed in developing formulas. One noteworthy one was the so-called "round" measurement proposed and used by Gregory (19). It was based on a tape line measurement from patella to patella around the rear thigh muscles, in a horizontal plane. In use with dairy and beef breeds, Gregory obtained correlations of 0.88 with live weight. By comparison, a correlation reported by Gregory for height at withers and live weight was 0.38. Wanderstock and Salisbury (44) made a similar study with 66 steers and obtained a correlation of 0.42 for patella to patella and 0.73 for height at withers with body weight. Another unusual measurement was used in developing the so-called "Crevat" formula, described and illustrated by Regensburger (34). This measurement was obtained by passing a tape line from the midline between the thighs around and over the back, approximately midway between the withers and hips, down the opposite side of the animal to the brisket and returning by a similar route on the opposite side of

the animal to the starting point. This was referred to as a "longitudinal circumference" of the trunk of the animal. Apparently it was designed in an effort to incorporate in some degree both the vertical and longitudinal "circumference" of the body in a single value. Regensburger concluded that, although the Crevat method gave slightly better results than heart girth, he could not recommend it for practice because of the existing high degree of variability.

Heart Girth Basis

Heart girth (chest circumference) was the measurement most extensively used as a basis for estimating body weight. Heart girth was used as a basis in 35 of the 46 reports of investigations reviewed. In 33 of these reports heart girth was used as a single component. In 11 it was used in combination with other measurements in developing factors or ratios. The most frequent use of heart girth was in developing tables, graphs, or tape lines to show directly the ratio of measurements to weight (1, 2, 4, 5, 7, 11, 12, 16, 18, 24, 25, 26, 28, 29, 33, 35, 39, 44, 46). Next in frequency was its use in studies of correlation. Correlations of heart girth with body weight varied with different breeds and types of animals, but were positive, highly significant, and of high magnitude in nearly all cases.

Some of the correlations: Bagot (3) 0.97 with Sinhala cattle; Bonsma and Neser (7) 0.95 for Bushveld cattle but only 0.48 for cattle in fat stock shows; Branton and Salisbury (9) 0.98 for Holstein and Guernsey bulls; Braude and Walker (10) 0.79 and 0.84 respectively for Shorthorn calves and cows; Hansson (20, 21) 0.95 to 0.96 in different groups of Swedish cattle; Johansson and Hildeman (25) 0.84 to 0.86 in Swedish cattle; Mullick (30) 0.96 in Hariana cows, 0.61 in bulls and 0.98 in the buffalo; Slagsvold (37) 0.92 in Red Polled bulls; Viega (41) 0.69 in Caracu cattle; Viega and Chieffi (42) 0.73 to 0.82 in Caracu cattle of different ages; and Wanderstock and Salisbury (44) 0.89 to 0.93 for different groups of Hereford and Angus heifers, cows and steers. Davis (18) reported correlations for males up to 18 months of age, Holstein 0.99; Jersey 0.98; Guernsey 0.98; Ayrshire 0.99; and for all breeds 0.98.

He also reported (17) for Holstein females at six-month intervals, birth through 24 months, as follows: birth 0.64; 6 months 0.85; 12 months 0.78; 18 months 0.78; and 24 months 0.73. Plohinskii and Masterova (32) reported a correlation of 0.85 between heart girth and the slaughter weight of cattle in a Moscow slaughter house.

A Sole Measurement

Formulas based on heart girth as the sole measurement also were prepared and adjusted to steers, heifers, and cows of various

breeds, types, and degrees of fatness. Bennett (4) claimed a high degree of accuracy within certain size areas, for steers. Hvidsten (24), working with six breeds—mostly Red Polled in Norway—developed a number of formulas but concluded that the one based on heart girth provided the best expression of weight, and that the significance was not increased by adding other measurements. He found that the ratio of heart girth to weight changed with age, breed, and nutrition level. He showed also that "dispersion by measuring" was 5 percent of body weight while "dispersion by weighing" was less than 1 percent of body weight.

Matievic (28) found it necessary to make adjustments for unusually proportioned animals in applying his formula developed in studies with animals of 4 different breeds in Austria. Misner (29) developed a number of different fomulas in addition to the one based on heart girth in studies with animals of 5 dairy breeds. He concluded that none of the formulas gave highly accurate estimates although the results were reasonably satisfactory when data for all of the 5 breeds were combined. Østergaard's (31) formula for Jerseys was adjusted for young cows, older cows, and "high pregnant" cows. Regensburger (35) in studies with large numbers of various European breeds developed a formula based on heart girth which he found of equal accuracy and more suitable for application than the so-called Crevat formula. Viega and Chieffi (43) found their live weight estimates by regression to be more highly accurate than those obtained by the Crevat formula.

Many Formulas

Various formulas have been developed in which heart girth was used in combination with one or more other body measurements. Bhandari *et al.* (6) used a formula based on heart girth and body length in studies with Indian cattle and with the buffalo. Singh (36) also used a formula based on heart girth, and a factor which varied with the magnitude of heart girth in studies of cattle in India. The formula appeared to give rather accurate estimates of weight. Horn (23) referred to early European studies in which the animal body was considered as a cylinder in estimating weight. One of the formulas used by Misner (29) employed heart girth, maximum girth and body length in calculating body volume as the frustum of a cone for weight estimation purposes. He did not consider his results as showing a high degree of accuracy.

Burt (15) also referred to the number of methods recommended for estimating body weight by calculating body volume as a cylinder or as the frustum of a cone. In his own studies of Dairy Shorthorns he used a formula embodying heart girth, paunch girth and body length. He concluded that heart girth was the best single

measurement for use in estimating body weight, but that by using two additional measurements greater accuracy was achieved. This is not in agreement with the conclusions of Hvidsten (24) and of Johansson and Hildeman (25) that weight can be estimated as well, or better, by heart girth as by a combination of measurements.

Height at Withers

Height at withers as well as heart girth has been used independently of other body measurements in the development of direct reading tables or graphs (8, 11, 12, 13, 14, 16). Correlations of height at withers with body weight have been reported by Braude and Walker (10) as 0.73 for Dairy Shorthorn calves at birth and 0.57 for cows. These investigators calculated correlations with weight for 12 other body measurements. The correlations varied from 0.84 for heart girth to 0.42 for head length in calves and from 0.83 for width at hooks to 0.13 for head width in cows. Heart girth had the second highest correlation in cows (0.79). Gregory (19) found the correlation of height at withers with body weight to be 0.38 in a group of 80 animals representing several breeds. Davis (17) reported correlations for Holstein females from birth by six month intervals to 24 months as follows: birth 0.69; 6 months 0.78; 12 months 0.70; 18 months 0.72; 24 months 0.65. Plohinskii and Masterova (32) reported a correlation of 0.80 between height at withers and slaughter weight. They also showed a correlation of 0.92 between live weight and slaughter weight. The correlation between heart girth and slaughter weight in this slaughter house study was 0.85. Viega (41) found a correlation of 0.57 between height at withers and body weight in a small group of Caracu cattle in Brazil.

Body Length Basis

Body length has not been extensively used as a basic measurement in estimating body weight. Brody (11) constructed a graph to show relationships between body length and weight in Holsteins and Jerseys. Bagot (3) showed a correlation of 0.96 between body length (shoulder to pin bone) and weight in Sinhala cattle. Braude and Walker (10) found length-weight correlations of 0.62 and 0.44 respectively in Dairy Shorthorn calves and cows. Davis (17) reported correlations for Holstein females by six-month intervals as follows: birth 0.62; 6 months 0.66; 12 months 0.40; 18 months 0.53; and 24 months 0.52. Plohinskii and Masterova (32) obtained a correlation of 0.75 between body length and slaughter weight (dressed weight) for cows in a Moscow slaughter house. Body length was used also in the formula reported by West (45) and by Bhandari *et al.* (6). The anatomical points used in measuring body length were not always specifically stated and may not have been the same in all studies.

Many Body Measurements

Although most investigators have confined their studies to one or two measurements, a few have made comparisons of the estimation value of a variety of body measurements. Bonsma and Neser (7) included 14 different items and concluded that chest girth was the one most closely correlated with body weight. Braude and Walker (10) made comparisons of estimates based on 13 different measurements. They found that in calves, heart girth gave the best indication of body weight, but that in cows, width of hooks showed the highest correlation (0.83) with heart girth second highest (0.79). Davis (17) in reporting measurement relationships to weight for Holstein females, birth through 24 months, found correlations as follows: length of top line 0.40 to 0.66; length of rump 0.49 to 0.76; heart girth 0.64 at birth, after that the range was 0.73 to 0.85; height at withers 0.65 to 0.78; height at hooks 0.56 to 0.76; depth of chest 0.53 to 0.81; width at hooks 0.64 to 0.85, all of which were significant at the 1 percent level. He also found that the regression on weight for each centimeter of girth was most consistent and lowest for heart girth as compared with other measurements.

Unpublished results of analyses of data on Holsteins and Jerseys at successive ages from 3 months to maturity at Beltsville, showed that among 8 body measurements studied heart girth was the most highly correlated with body weight. As already shown, Johansson and Hildeman (25) found that live weight estimated on two or more body measurements was no more accurate than estimates on heart girth alone and Hvidsten (24) found that heart girth provided the best expression of body weight. In one report Regensburger (34) concluded that the method proposed by Crevat, which involved more than one measurement, gave slightly better estimates than those based on heart girth but that because of the high degree of variability, he could not recommend it. In a later report (35) the same author concluded that the use of a formula based on heart girth actually gave better estimates than the Crevat method. Viega and Chieffi (43) also found the Crevat method less accurate than regressions based on heart girth alone. Burt (15) was one of the few who found that a formula based on more than one measurement gave better results than one based on a single measurement.

It was recognized by various investigators that the accuracy of estimates of weight based on heart girth may be affected by the breed, type, age, size, and condition of the animal, and that adjustments for such variables may be desirable in the interests of greater accuracy. It appears to be the consensus of opinion, however, that estimates based on measurement of heart girth

in most cases gave the highest degree of accuracy.

In some cases formulas derived from heart girth and other measurements gave results of equal accuracy to estimates based on heart girth alone. Even in such cases, however, there was a tendency to recommend using heart girth alone because of simplicity in application.

Source of Data

The data on which this study is based were obtained from two sources. Data designated "Beltsville" are body measurements of purebred animals in the dairy herd of the Dairy Cattle Research Branch, Animal Husbandry Research Division, United States Department of Agriculture, Beltsville, Maryland.

These measurements were recorded at designated periods of life from 3 months to maturity. The accumulation of data at Beltsville represents a period of 30 years (1924-1954). Approximately 3,500 sets of measurements were included. Data designated "Nebraska" were obtained over a period of 20 years on purebred animals in the dairy herd at the University of Nebraska. These data were recorded monthly, beginning at birth and continuing to 7 years of age unless death or disposal had occurred prior to that age. Weights were taken at a uniform time of day.

The weights of animals from both sources were obtained by weighing on a platform scale of suitable size and capacity, and heart girth was measured with a non-stretch woven tape, fitted snugly around the animal just back of the shoulders, with the animal standing squarely on a level surface. The data from both sources were transferred to punch cards at the Dairy Cattle Research Branch, and the statistical analyses were made by Biometrical Services, Agricultural Research Service, United States Department of Agriculture.

Statistical Analysis

Fifth degree orthogonal polynomial curves were fitted to the means of weight for two centimeter interval classes for each of the six sets of data; namely Nebraska and Beltsville Holstein and Jersey females and the data on Holstein and Jersey males from Nebraska. In addition, the data on Holstein and Jersey females from the two stations were combined over stations and fifth degree orthogonal polynomial curves were fitted to the combined means for each breed separately.

Tests of significance showed that each of the five partial regressions accounted for a significant ($P < .05$) or highly significant ($P < .01$) amount of the variation in weight in all groups except for the two male groups. The fourth and fifth degree terms accounted for an insignificant amount of variation for the

Holstein males and the last three degrees were each insignificant in the case of Jersey males.

The estimated weights were computed from the fifth degree polynomial prediction equation separately for each group and for each centimeter in heart girth from the lowest measurements observed to the highest. To avoid rounding errors, these were computed in floating decimal on an electronic computer.

Coefficients of variation were calculated from the variation in weight among animals which measured the same (nearest cm.) in heart girth. Weighted averages of these coefficients of variation were then computed for 10 cm. interval groups and finally for all data in each group. Coefficients of variation for the Holstein and Jersey female data combined over station were obtained by weighting the coefficients of variation between stations by the number of measurements at each station. Since the polynomial curves were actually fitted to the means of two centimeter interval classes and since the curves would not fit these means exactly, these coefficients of variation provide a minimum estimate of error in estimating weight from the heart girth measurement.

Discussion

The discussion is based upon a series of tables which present the heart girth-weight relationship for males and females of the Holstein and Jersey breeds. Separate listing was made of data from Nebraska and from Beltsville concerning Holstein and Jersey females, and then the data were combined. The measurements for the study were transferred to punch cards and then studied statistically as was explained in a previous section.

Holstein, Jersey Females

Table 1 presents in parallel columns, for Holstein and Jersey females, the heart girth-weight relationship data from Nebraska and from Beltsville and the pooled data along with the D.H.I.A. Standard. That Standard is the present tape (26) which is used in measuring dairy cattle to determine weight. Nebraska Holsteins were lighter in weight than Beltsville Holsteins through the 92 cm. heart girth and were the same weight or heavier than the Beltsville Holsteins through 117 cm. of heart girth although the differences were small. From 118 cm. heart girth on, Beltsville Holsteins exceeded the Nebraska Holsteins in weight with the spread gradually increasing to the largest girths. The cause of this disparity in weight is not clear unless it was due to a somewhat higher fat condition of the Beltsville animals. Comparisons of other body measurements of the two groups of cattle in data not shown indicate only minor differences. The D.H.I.A.

Table 1. Relation of Heart (Chest) Girth to Weight for Holstein and Jersey Females

Heart girth	Weight						
	D.H.I.A. Standard	Nebraska Holsteins	Beltsville Holsteins	All Holsteins	Nebraska Jerseys	Beltsville Jerseys	All Jerseys
cm.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
61					56		57
62					54		56
63					53		54
64					53		54
65					53		54
66	80				53		54
67	82				54		54
68	83				56		55
69	85	84		82	57		57
70	86	83		82	59		59
71	89	83		82	61		61
72	92	84		83	64		63
73	94	84		84	67		66
74	95	85		85	70		69
75	98	87		87	73		72
76	101	89		89	77		76
77	103	91		91	80		79
78	107	93		94	84		83
79	108	96		96	88	101	87
80	113	99		100	93	103	92
81	118	102		103	97	105	96
82	122	105		106	102	107	101
83	124	109		110	106	110	105
84	128	113		114	111	113	110
85	133	117		118	116	116	115
86	137	121		122	121	120	120
87	142	126		127	126	124	125
88	144	130		131	132	128	130
89	148	135	145	136	137	132	136
90	153	140	147	141	142	137	141
91	157	146	150	146	147	142	147
92	162	151	153	152	153	147	152
93	164	156	156	157	158	152	158
94	168	162	160	163	164	157	163
95	174	168	165	168	169	163	169
96	179	174	169	174	175	168	175
97	181	180	174	180	181	174	180
98	186	186	180	186	186	180	186
99	192	192	185	192	192	186	192
100	199	199	191	198	198	192	198
101	207	205	198	205	204	198	204
102	209	212	204	211	210	204	209
103	216	218	211	218	216	210	215
104	224	225	217	224	221	217	221
105	231	232	224	231	227	223	227
106	238	239	232	238	233	230	233
107	241	245	239	245	240	236	240
108	248	252	246	251	246	243	246
109	256	260	254	258	252	249	252
110	265	267	262	266	258	256	258
111	273	274	270	273	264	263	264
112	276	281	278	280	270	270	271
113	284	289	286	287	277	277	277
114	293	296	294	295	283	284	284
115	302	304	302	302	290	291	290
116	305	311	310	310	296	298	297
117	314	319	318	317	303	305	303
118	324	326	327	325	309	312	310
119	333	334	335	333	316	319	317
120	342	342	343	341	323	327	324
121	345	350	352	349	330	334	330
122	354	358	360	357	337	341	337
123	363	366	369	365	344	349	345
124	373	374	378	373	351	357	352
125	382	382	386	381	358	364	359
126	385	390	395	389	366	372	367
127	394	399	404	398	373	380	374
128	403	407	412	406	381	388	382
129	412	415	421	415	389	396	390
130	415	424	430	424	397	404	398
131	425	432	439	432	405	412	406

Table 1. Relation of Heart (Chest) Girth to Weight for Holstein and Jersey Females

Table 1.—Continued

Heart girth	Weight						
	D.H.I.A. Standard	Nebraska Holsteins	Beltsville Holsteins	All Holsteins	Nebraska Jerseys	Beltsville Jerseys	All Jerseys
cm.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
132	434	441	448	441	413	421	414
133	444	450	457	450	421	429	422
134	454	459	466	459	429	438	431
135	457	468	475	468	438	447	439
136	467	477	485	477	446	456	448
137	477	486	494	487	455	465	457
138	487	495	503	496	464	474	466
139	498	504	513	505	473	483	475
140	502	513	523	515	483	492	485
141	513	523	532	525	492	502	494
142	525	532	542	535	502	512	504
143	537	542	552	545	511	522	514
144	541	552	562	555	521	532	524
145	553	562	572	565	531	542	534
146	565	572	583	575	541	553	544
147	578	582	593	585	552	563	555
148	591	592	604	596	562	574	566
149	595	603	615	606	573	585	576
150	608	613	625	617	584	596	588
151	621	624	637	628	595	607	599
152	635	634	648	639	606	619	610
153	649	645	659	650	617	631	622
154	653	656	671	662	629	643	633
155	668	667	683	673	640	655	645
156	683	679	695	684	652	667	657
157	698	690	707	696	664	680	669
158	713	702	719	708	676	692	682
159	717	713	732	720	688	705	694
160	732	725	745	732	700	718	707
161	748	737	758	744	713	732	719
162	763	749	771	757	725	745	732
163	768	761	785	769	738	759	745
164	784	774	799	782	750	773	758
165	800	786	813	794	763	787	771
166	815	799	827	807	776	801	784
167	832	812	841	821	789	816	797
168	837	825	856	834	802	830	810
169	853	838	871	847	815	845	823
170	870	852	886	861	828	860	837
171	887	865	901	874	841	875	850
172	904	879	916	888	854	890	863
173	909	892	932	902	866	905	876
174	927	906	948	916	879	921	889
175	946	921	965	930	895	937	905
176	964	935	981	945	905	952	915
177	970	949	997	959	917	967	928
178	988	964	1014	974	930	983	941
179	1007	978	1031	988	942	999	954
180	1025	993	1048	1003	955	1015	966
181	1044	1008	1065	1018	967	1031	978
182	1050	1023	1083	1033	978	1047	990
183	1070	1038	1100	1049	990	1062	1002
184	1089	1054	1118	1064	1001	1078	1013
185	1108	1069	1136	1079	1012	1094	1024
186	1128	1085	1154	1095	1023	1110	1035
187	1134	1100	1172	1111	1033	1125	1046
188	1153	1116	1190	1126	1044	1141	1056
189	1174	1132	1208	1142	1053	1156	1065
190	1194	1148	1226	1158	1062	1172	1074
191	1214	1164	1244	1174	1071	1187	1083
192	1220	1180	1263	1190	1079	1202	1091
193	1241	1197	1281	1206	1087	1216	1098
194	1261	1213	1299	1223	1094	1231	1105
195	1281	1230	1317	1239	1100	1245	1111
196	1288	1246	1335	1255	1106	1258	1117
197	1309	1263	1352	1272	1111	1272	1121
198	1330	1279	1370	1288	1116	1285	1125
199	1351	1296	1387	1304	1119		1128
200	1372	1313	1404	1321	1122		1130

Table 1. Relation of Heart (Chest) Girth to Weight for Holstein and Jersey Females

Table 1.—Continued

Heart girth	Weight						
	D.H.I.A. Standard	Nebraska Holsteins	Beltsville Holsteins	All Holsteins	Nebraska Jerseys	Beltsville Jerseys	All Jerseys
cm.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
201	1379	1329	1421	1337			
202	1400	1346	1438	1354			
203	1422	1363	1454	1370			
204	1443	1379	1470	1387			
205	1464	1396	1485	1403			
206	1471	1413	1500	1419			
207	1492	1429	1515	1435			
208	1513	1446	1529	1452			
209	1534	1462	1542	1468			
210	1541	1479	1555	1484			
211	1562	1495	1567	1500			
212	1583	1511	1578	1515			
213	1604	1527	1589	1531			
214	1625	1543	1599	1546			
215	1633	1559	1607	1562			
216	1654	1574	1615	1577			
217	1675	1590		1592			
218	1696	1605		1607			
219	1716	1620		1621			
220	1724	1634		1635			
221	1745	1649		1649			
222	1766	1663		1663			
223	1787	1677		1676			
224	1795	1690		1689			
225	1816	1703		1702			
226	1837	1716		1714			
227	1857	1728		1726			
228	1878	1740		1737			

Standard for heart girth-weight relationships is higher than either Nebraska Holsteins or Beltsville Holsteins for the smaller girths through 97 cm., then is much the same for both groups through 125 cm. From 126 cm. on, it is below both groups through 151 cm. heart girth. From 152 cm. through 211 cm. heart girth, the D.H.I.A. Standard is between the groups and from 212 cm. heart girth on, the D.H.I.A. Standard is higher than for either group.

The "All Holsteins" column which is a statistical blend of the Nebraska and Beltsville data shows lower weights than the D.H.I.A. Standard through 97 cm. heart girth. From that measurement on, the two are the same through 134 cm. heart girth. From 135 cm. heart girth on the D.H.I.A. Standard for weight is lower through 156 cm. heart girth, the difference varying from 1 to 14 pounds. Beginning with 157 cm. heart girth the D.H.I.A. Standard is higher than the All Holsteins, with two exceptions, for the remainder of the measurements. The weight differences varied from zero to 19 pounds between 157 cm. and 179 cm. heart girth. From that latter heart girth on, the differences tended to increase, being 141 pounds at 228 cm. heart girth. The All Holstein heart girth-weight relationships are believed to be the best figures so far presented for Holsteins in the United States.

Nebraska Jerseys

Nebraska Jerseys at girths through 84 cm. had lower weights than the Beltsville Jerseys. From 85 cm. heart girth they were the same or heavier in weight than the Beltsville Jerseys through 113 cm. of heart girth although the weight differences were small. Beginning with 114 cm. of heart girth, the Beltsville Jerseys were heavier through the remainder of the measurements. These differences were small, varying from 1 to 10 pounds through 142 cm. heart girth. From the 143 cm. heart girth through 162 cm. heart girth, the Beltsville Jerseys were heavier than the Nebraska Jerseys with differences of from 11 to 20 pounds. From that heart girth on, through the rest of the measurements, the Beltsville Jerseys showed increasingly greater differences in weight amounting to 169 pounds at 198 cm. of heart girth. Thus the Beltsville Jerseys tended to be much heavier at the higher heart girths than Nebraska Jerseys although the numbers of measurements involved in both cases were small. Possibly the same explanation offered for the weight differences in Holsteins is pertinent.

The "All Jerseys" represents a statistical blend of the data from the two sources and is believed to represent the best figures now available for the Jersey breed in the U.S.A. The D.H.I.A. Standard for weight as compared with the All Jersey weights is higher from 66 cm. through 97 cm., the difference at the smaller girth being 26 to 29 pounds and then gradually decreasing so that they are alike at 98 cm. heart girth. From 98 cm. through 116 cm. the D.H.I.A. Standard compared with All Jerseys ranged from the same to 12 pounds higher. Beginning with 117 cm. heart girth through 157 cm. the D.H.I.A. Standard was higher than the All Jerseys, the difference ranging from 11 to 29 pounds. Beginning with 158 cm. heart girth the D.H.I.A. Standard showed a progressively higher weight differential up to 242 pounds at 200 cm. heart girth.

Holstein, Jersey Males

In Table 2 the heart girth-weight relationships for Holstein and Jersey males are presented based on Nebraska data, and a comparison with the D.H.I.A. Standard. This was done because it has been a common practice to use that tape standard for determining the weight of males.

The D.H.I.A. Standard is much too high for both Holstein and Jersey males from 66 cm. through 92 cm. heart girth. From 93 cm. through 129 cm. heart girth the Holstein male weights vary 1 to 8 pounds from the D.H.I.A. Standard, tending to be heavier. From 130 cm. through 170 cm. heart girth the Holstein males ex-

Table 2. Relation of Heart (Chest) Girth to Weight for Holstein and Jersey Males

Heart girth	Weight		
	D.H.I.A. Standard	Nebraska Holsteins	Nebraska Jerseys
cm.	lbs.	lbs.	lbs.
59			60
60			58
61			57
62			56
63			56
64			56
65			56
66	80		57
67	82	75	58
68	83	76	60
69	85	76	62
70	86	77	64
71	89	79	67
72	92	80	70
73	94	82	72
74	95	84	76
75	98	86	79
76	101	89	82
77	103	91	86
78	107	94	90
79	108	98	93
80	113	101	97
81	118	104	101
82	122	108	106
83	124	112	110
84	128	116	114
85	133	120	118
86	137	125	123
87	142	129	127
88	144	134	132
89	148	139	136
90	153	144	141
91	157	149	146
92	162	154	151
93	164	159	156
94	168	165	161
95	174	170	166
96	179	176	171
97	181	182	176
98	186	188	181
99	192	194	187
100	199	200	192
101	207	206	198
102	209	212	203
103	216	219	209
104	224	225	215
105	231	232	221
106	238	239	227
107	241	246	233
108	248	252	240
109	256	259	246
110	265	267	253
111	273	274	260
112	276	281	267
113	284	288	274
114	293	296	281
115	302	303	289
116	305	311	296
117	314	319	304
118	324	327	312
119	333	335	320
120	342	343	328
121	345	351	336
122	354	359	345
123	363	368	353
124	373	376	362
125	382	385	371
126	385	393	379
127	394	402	388
128	403	411	397

Heart girth	Weight		
	D.H.I.A. Standard	Nebraska Holsteins	Nebraska Jerseys
cm.	lbs.	lbs.	lbs.
129	412	420	406
130	415	429	415
131	425	438	424
132	434	448	433
133	444	457	442
134	454	466	451
135	457	476	460
136	467	486	468
137	477	496	477
138	487	506	485
139	498	516	
140	502	526	
141	513	536	
142	525	546	
143	537	557	
144	541	568	
145	553	578	
146	565	589	
147	578	600	
148	591	611	
149	595	622	
150	608	633	
151	621	644	
152	635	656	
153	649	667	
154	653	679	
155	668	691	
156	683	702	
157	698	714	
158	713	726	
159	717	738	
160	732	750	
161	748	762	
162	763	774	
163	768	786	
164	784	798	
165	800	810	
166	815	823	
167	832	835	
168	837	847	
169	853	859	
170	870	872	
171	887	884	
172	904	896	
173	909	908	
174	927	920	
175	946	934	
176	964	944	
177	970	956	
178	988	968	
179	1007	980	
180	1025	991	
181	1044	1003	
182	1050	1014	
183	1070	1025	
184	1089	1036	
185	1108	1047	
186	1128	1058	
187	1134	1068	
188	1153	1078	
189	1174	1088	
190	1194	1098	

ceeded the D.H.I.A. Standard by from 2 to 27 pounds. From heart girth 171 cm. through 190 cm. the weights of the Holstein males were less than the Standard, ranging from 1 to 96 pounds. In the case of the Jersey males from 66 cm. to 92 cm. heart girth inclusive the Jerseys ranged from 11 to 24 pounds lighter than the Standard. Between 93 and 134 cm. heart girths their weights were from 0 to 14 pounds below the Standard. From 135 cm. heart girth through 138 cm. the weights for the Jersey males varied from 0 to 3 pounds from the Standard.

Table 3 shows the coefficients of variation for the heart girth-weight relationship for Holstein and Jersey males. In effect these coefficients indicate the mathematical range of error in weight for any measurement by ranges of heart girth. Thus any weight measurement for the heart girth range 70-79 cm. for Holsteins, as for example 98 pounds at a heart girth of 79 cm., would be subject to an error of 10.99 per cent. That means that in pounds the error might be as much as 10.77. The probability is about .67 that an animal with a 79 cm. heart girth weighs between 81 and 109 pounds. The average coefficient of variation for all ranges of Holsteins is 10.04. The coefficients of variation for Jersey male weights are in most cases higher, the average being 13.92.

Breed and Set Comparisons

In Table 4 the heart girth-weight relationships are presented for all Holsteins and all Jersey females, and Nebraska Holstein and Jersey males. This table is presented in order that the similarities and differences for the breeds and sexes may be apparent. The Jersey females and males have much the same weights throughout the range of heart girth comparisons. The males

Table 3. Coefficients of Variation—Heart Girth—Weight Relationship—for Holstein and Jersey Males

Heart girth	Nebraska			
	Holstein Males		Jersey Males	
Class range	Measurements	Coefficient of Variation	Measurements	Coefficient of Variation
cm.	No.		No.	
60- 69			93	14.94
70- 79	106	10.99	102	18.36
80- 89	294	13.05	75	15.25
90- 99	169	13.98	59	12.34
100-109	146	11.39	44	9.43
110-119	135	8.95	34	10.04
120-129	121	8.73	17	7.01
130-139	113	7.41	18	8.01
140-149	120	7.27		
150-159	89	6.45		
160-169	70	5.38		
170-179	44	7.74		
180-189	13	5.58		
190-199	7	4.61		
200-209	14	4.71		
Total	1441		442	
Average		10.04		13.92

Table 4. Relation of Heart Girth to Weight for all Holstein and Jersey Females and Nebraska Holstein and Jersey Males

Heart girth	Weight				Heart girth	Weight			
	All Holstein females	Nebraska Holstein males	All Jersey females	Nebraska Jersey males		All Holstein females	Nebraska Holstein males	All Jersey females	Nebraska Jersey males
cm.	lbs.	lbs.	lbs.	lbs.	cm.	lbs.	lbs.	lbs.	lbs.
59				60	121	349	351	330	336
60				58	122	357	359	337	345
61			57	57	123	365	368	345	353
62			56	56	124	373	376	352	362
63			54	56	125	381	385	359	371
64			54	56	126	389	393	367	379
65			54	56	127	398	402	374	388
66			54	57	128	406	411	382	397
67		75	54	58	129	415	420	390	406
68		76	55	60	130	424	429	398	415
69	82	76	57	62	131	432	438	406	424
70	82	77	59	64	132	441	448	414	433
71	82	79	61	67	133	450	457	422	442
72	83	80	63	70	134	459	466	431	451
73	84	82	66	72	135	468	476	439	460
74	85	84	69	76	136	477	486	448	468
75	87	86	72	79	137	487	496	457	477
76	89	89	76	82	138	496	506	466	485
77	91	91	79	86	139	505	516	475	
78	94	94	83	90	140	515	526	485	
79	96	98	87	93	141	525	536	494	
80	100	101	92	97	142	535	546	504	
81	103	104	96	101	143	545	557	514	
82	106	108	101	106	144	555	568	524	
83	110	112	105	110	145	565	578	534	
84	114	116	110	114	146	575	589	544	
85	118	120	115	118	147	585	600	555	
86	122	125	120	123	148	596	611	566	
87	127	129	125	127	149	606	622	576	
88	131	134	130	132	150	617	633	588	
89	136	139	136	136	151	628	644	599	
90	141	144	141	141	152	639	656	610	
91	146	149	147	146	153	650	667	622	
92	152	154	152	151	154	662	679	633	
93	157	159	158	156	155	673	691	645	
94	163	165	163	161	156	684	702	657	
95	168	170	169	166	157	696	714	669	
96	174	176	175	171	158	708	726	682	
97	180	182	180	176	159	720	738	694	
98	186	188	186	181	160	732	750	707	
99	192	194	192	187	161	744	762	719	
100	198	200	198	192	162	757	774	732	
101	205	206	204	198	163	769	786	745	
102	211	212	209	203	164	782	798	758	
103	218	219	215	209	165	794	810	771	
104	224	225	221	215	166	807	823	784	
105	231	232	227	221	167	821	835	797	
106	238	239	233	227	168	834	847	810	
107	245	246	240	233	169	847	859	823	
108	251	252	246	240	170	861	872	837	
109	258	259	252	246	171	874	884	850	
110	266	267	258	253	172	888	896	863	
111	273	274	264	260	173	902	908	876	
112	280	281	271	267	174	916	920	889	
113	287	288	277	274	175	930	934	905	
114	295	296	284	281	176	945	944	915	
115	302	303	290	289	177	959	956	928	
116	310	311	297	296	178	974	968	941	
117	317	319	303	304	179	988	980	954	
118	325	327	310	312	180	1003	991	966	
119	333	335	317	320	181	1018	1003	978	
120	341	343	324	328	182	1033	1014	990	

Table 4. Relation of Heart Girth to Weight for all Holstein and Jersey Females and Nebraska Holstein and Jersey Males

Table 4—Continued

Heart girth	Weight				Heart girth	Weight			
	All Holstein females	Nebraska Holstein males	All Jersey females	Nebraska Jersey males		All Holstein females	Nebraska Holstein males	All Jersey females	Nebraska Jersey males
cm.	lbs.	lbs.	lbs.	lbs.	cm.	lbs.	lbs.	lbs.	lbs.
183	1049	1025	1002		211	1500			
184	1064	1036	1013		212	1515			
185	1079	1047	1024		213	1531			
186	1095	1058	1035		214	1546			
187	1111	1068	1046		215	1562			
188	1126	1078	1056		216	1577			
189	1142	1088	1065		217	1592			
190	1158	1098	1074		218	1607			
191	1174		1083		219	1621			
192	1190		1091		220	1635			
193	1206		1098		221	1649			
194	1223		1105		222	1663			
195	1239		1111		223	1676			
196	1255		1117		224	1689			
197	1272		1121		225	1702			
198	1288		1125		226	1714			
199	1304		1128		227	1726			
200	1321		1130		228	1737			
201	1337								
202	1354								
203	1370								
204	1387								
205	1403								
206	1419								
207	1435								
208	1452								
209	1468								
210	1484								

were the same weight or heavier in the heart girth range from 63 cm. through 88 cm., the amount varying from zero to 7 pounds. In the range from 89 cm. through 116 cm. the Jersey females were the same weight or exceeded the males in weight from 1 to 7 pounds. In the heart girth range from 117 cm. through 138 cm. the males exceeded the females in weight from 1 to 21 pounds with the greatest differences being for the larger heart girths.

A somewhat different pattern of relationships existed between Holstein males and females. From a heart girth measurement of 69 cm. through 75 cm. the females exceeded the males in weight from 1 to 6 pounds. Between the heart girths of 76 cm. and 175 cm. the males weighed the same or exceeded the weights of the females by from 1 to 18 pounds. For the range of heart girth 76 cm. through 130 cm. the weight difference between the sexes never exceeded five pounds. From that point through 175 cm. the differences in weights between the males and the females increased much more. For heart girth 176 cm. to 190 cm. the male Holsteins weighed less than the females, the difference ranging from 1 to 60 pounds with the differences tending to increase as the heart girth increased.

The breed comparisons also showed differences. Not until the 82 cm. heart girth did the males and females of the Holstein and Jersey breeds have substantially the same weight, and at that point the Jersey females were lower than the Jersey males and the Holstein males and females. From 83 cm. heart girth through 102 cm. heart girth the differences between the males and females of the several breeds were under 10 pounds. Beginning with a heart girth of 103 cm. and through 138 cm. the differences increased, ranging from 10 to 40 pounds. The gap between the breeds tended to widen with the larger heart girths, with the Jersey females and males always substantially lighter in weight than the animals of comparable girth of the Holstein breed. Comparisons beyond the 138 cm. heart girth do not include Jersey males. The Jersey females, for measurements 139 cm. through 200 cm., varied from the weights of the Holstein females from 20 to 191 pounds. The tendency was for the differences to increase with the greater heart girths.

It seems evident from the data presented that while there are heart girth ranges where the weights of the males and females of each breed are much alike, that at the greater heart girths, the females tended to be heavier than the males. Unfortunately, the data do not include figures for mature males. As between the Jersey and Holstein breeds, at the smaller heart girths, the Jerseys were considerably lighter. Then there was a range in heart girths when the Jerseys were much like the Holsteins. At the larger heart girths, the Jerseys showed a wider difference from the Holsteins in weight.

Table 5 shows the coefficient of variation in heart girth-weight relationship for Holstein and Jersey females. It is intended to be used with Table 4 in determining the range in weight that may be expected for any particular heart girth measurement. It can be used in the same manner as Table 3. As was the case with that table, there were large coefficients of variation for the smaller girths, which represented the younger growing animals. The reason for the larger coefficients of variation for the Nebraska animals, as compared with the Beltsville animals, is not apparent.

To use the data presented in Table 4, along with Table 5, the weight for a particular heart girth may be determined by consulting Table 4. An illustration is a Holstein female for a heart girth of 120 cm. is estimated to weigh 341 pounds. Consulting Table 5, the coefficient of variation for all Holsteins is 7.79. Thus the variation to be expected is (341 x .0779) 27 pounds. The probability is .67 that animals of that heart girth may be expected to weigh between 324 and 368 pounds.

Table 5. Coefficients of Variation—Heart Girth Weight Relationship for Holstein and Jersey Females

Heart girth	HOLSTEIN FEMALES						JERSEY FEMALES					
	NEBRASKA		BELTSVILLE		ALL		NEBRASKA		BELTSVILLE		ALL	
Class range	Measurements	Coefficient of variation	Measurements	Coefficient of variation	Measurements	Coefficient of variation	Measurements	Coefficient of variation	Measurements	Coefficient of variation	Measurements	Coefficient of variation
cm.	No.		No.		No.		No.		No.		No.	
60- 69							120	14.71			120	14.72
70- 79	181	12.66			181	12.66	170	18.79			170	18.79
80- 89	313	16.79			313	16.79	110	14.80	104	7.78	214	11.39
90- 99	218	13.66	58	6.41	276	12.14	123	13.33	137	6.12	260	9.53
100-109	238	11.04	136	5.11	374	8.88	130	11.40	52	3.88	182	9.25
110-119	249	11.06	37	6.11	286	10.42	162	9.78	169	5.94	331	7.82
120-129	283	9.21	134	4.79	417	7.79	185	8.93	84	5.21	269	7.77
130-139	337	8.91	82	5.32	419	8.21	230	7.71	177	5.09	407	6.56
140-149	368	7.91	132	4.87	500	7.11	349	7.21	190	5.45	539	6.59
150-159	499	7.94	152	4.34	651	7.10	439	7.42	183	5.71	622	6.92
160-169	594	7.26	106	4.13	700	6.79	831	7.44	277	6.87	1108	7.30
170-179	756	7.66	188	5.85	944	7.30	972	6.03	270	5.60	1242	5.94
180-189	972	7.02	292	6.00	1264	6.78	573	5.60	121	5.00	694	5.50
190-199	1755	6.80	266	5.12	2021	5.68	162	6.61	13	2.91	175	6.34
200-209	1902	6.22	116	5.42	2018	6.17	13	8.50			13	8.50
210-219	814	5.92	18	4.47	832	5.89						
220-229	117	5.52			117	5.52						
Total	9596		1717		11313		4569		1777		6346	
Average		7.77		5.26		7.39		8.08		5.81		7.45

Summary

Fifth degree orthogonal polynomials were fitted to the mean weights of two centimeter heart girth interval classes separately for 9,596 measurements on 248 Nebraska Holstein females, 1,717 measurements on 514 Beltsville Holstein females, 4,569 measurements on 140 Nebraska Jersey females, 1,777 measurements on 478 Beltsville Jersey females, 1,441 measurements on 227 Nebraska Holstein males and 442 measurements on 96 Nebraska Jersey males. Measurements for heart girth and weight were available from birth to seven years of age on most of these groups.

Holstein and Jersey female data from Nebraska and Beltsville were combined and the same type of curve fitted to the combined data. Tables are given which provide comparisons of the estimated weights for each centimeter between the different sets of data and with the D.H.I.A. Standard.

Estimated Weights

The estimated weights clearly show that the relationship of heart girth measurement to weight is different for Holsteins than for Jerseys, especially at the higher heart girth measurements. In addition, there was some indication that the estimates for the same breed at the two locations were also different, especially in mature Jerseys. However, estimated weights from the combined data separately for each breed should be considerably more accurate than the present D.H.I.A. Standard.

Coefficients of variability were computed from the variability among weights when the animals measured the same in heart girth. Weighted averages of these coefficients of variability are given by 10 cm. interval groups separately for the different groups of animals. The overall weighted averages of the coefficients of variability were 7.77 and 5.26 for the Holsteins, and 8.08 and 5.81 for the Jerseys from Nebraska and Beltsville, respectively. Coefficients of variability for the Nebraska males were 10.04 and 13.92 for the Holsteins and Jerseys, respectively. The coefficient of variability was consistently larger for the small heart girth measurements in the Nebraska data. Very little of this trend existed in the Beltsville data.

It is believed that a single set of measurements such as the D.H.I.A. Standard is not accurate enough to use for determining the heart girth-weight relationship of such diverse breeds as Holstein and Jersey. It is suggested that the use of accompanying tables will prove more satisfactory for determining the weight of cattle than previous standards. Additional and complete tables for both sexes would also be desirable. However, the inadequacy of the data regarding males does not make this possible at the present time.

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